Multi Quantum Well (MQW) Lasers at 1550 nm Fabricated With a Single Epitaxial Selective Growth Step by MOVPE and Without Waveguide Etching

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Introduction Selective area growth (SAG) has proven to be a powerful tool for the realisation of Photonic Integrated Circuits (PIC's)[1]. Several groups have reported the fabrication of lasers or even PIC's by means of selective growth without the need for waveguide etching. Good performance and uniformity results were obtained [2,3]. However the fabrication of these devices needed at least two or three growth steps. We present some first results on lasers obtained with a *single* epitaxial growth step without any need for waveguide etching.

Growth procedure and results Prior to the selective growth pairs of SiO_2 stripes are defined on the n-type (100) exact InP substrate along the [110] direction. For all growth experiments we used mask openings (m_o) of 2.2, 2.9, 3.6 and 5.7 µm combined with mask widths (m_w) of 5, 10 ,15 , 20 and 30 µm. MOVPE at 76 Torr is used as growth technique with TMI, TMG, AsH_3 and PH_3, DEZ and H_2S (res. p and n doping) as precursors. Smooth (111) side facets and perfect selectivity could be obtained for SAG of InP with SAG adapted growth conditions (Fig 1a). However when growing InGaAs or quaternary material, compositional changes occur in the SAG versus planar growth, making it necessary to apply some pre tensile strain in the layers. For device applications flat interfaces between the different layers are also desired. SEM pictures Fig. 1b and c show cross sections for different m_o and m_w. The grown layer stack consisted of an InP buffer layer (100nm), 85 nm InGaAs sandwiched between two 85 nm thick Q1.25 layers, and 50 nm InP top cladding. The SAG effect enhances the growth rate depending upon m_o and m_w. The growth rate change is shown in Fig. 2 for different m_o and m_w. Both the composition and thickness modifications during SAG result in a bandgap shift when Quantum Wells are applied. Room temperature photoluminescence (PL) measurements on a sample containing an InGaAs QW stack with Q1.25 Barriers show this bandgap shift (Fig. 3). A shift of 150 nm can be achieved for all opening widths when m_w is increased from 5 µm to 30 µm, making this simple growth and processing technique very suitable for monolithic active-passive integration

Fabry-Perot laser fabrication For the realisation of a laser structure with a single selective epitaxial growth step the maximum height of the SAG ridges is limited. This means that, certainly in the case of the two narrowest mask openings used, the heavily doped InGaAs contacting layer will be situated rather close to the optical mode, resulting in high absorption losses. Calculations show that this specific loss can be as high as 5 dB/cm for the SAG mesa of which the calculated TE optical mode profile is shown in Fig.4. The layer stack of the grown laser structure consisted of 5 InGaAs QW's (2.2 nm) with 14 nm thick Q1.25 barrier material, sandwiched between 92 nm thick Q1.25 SC layers. The p-type InP upper cladding is 315 nm thick and is capped by a 45 nm thick p-type InGaAs contacting layer, grown at atmospheric pressure. All thicknesses refer to the planar non-masked region. After growth an insulating polyimide layer is deposited on the sample (the SiO_2 stripes do not need to be removed), followed by etching this layer through small windows along the SAG stripes. Polishing the substrate and applying metal contacts finish the processing. Fig.5 shows a SEM pictures of the resulting cross section when processing was finished. Fig. 6 shows the typical LI plot (normalised power) of a SAG Fabry-Pérot laser operated as cleaved at room temperature under pulsed current injection (500 ns pulse length, 10% DC). Laser operation was observed at 1550 nm (400 µm long laser cavity with m_w 30 µm and m_o 5.7 µm).

Conclusion We succeeded in fabricating MQW lasers by means of a *single* selective growth step (SAG) and without etching of waveguide ridges. The devices show satisfactory performance certainly for a first trial. Optimisation of all involved layer thicknesses (core layers, InP cladding layer) will greatly contribute to an improvement of the performance. The bandgap shift as measured with PL holds promises for active-passive integration by means of a simple -single growth- integration method.

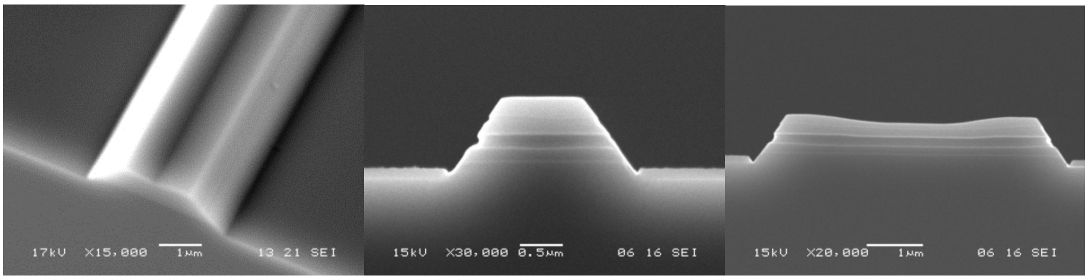
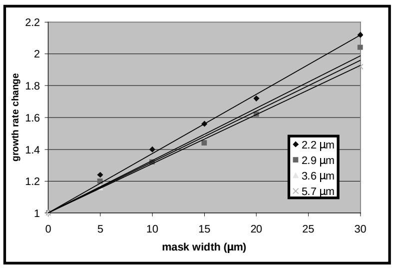


Fig 1 a, b and c SEM pictures of SAG mesa's
a)SAG of InP
b) and c) Cross section of SAG grown layer stack consisting of InGaAs sandwiched between Q1.25 with m_o 2.2 µm, m_w 30 µm (b) and m_o 5.7 µm, m_w 30 µm (c)



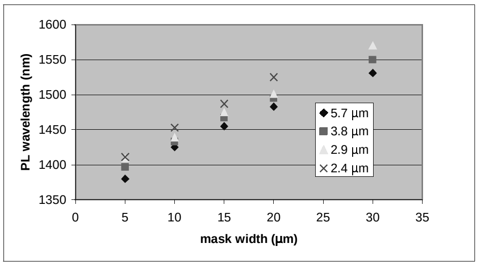
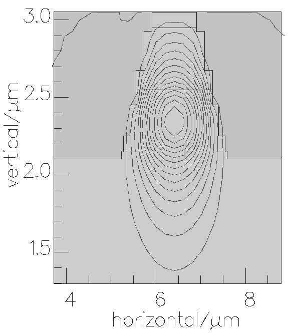


Fig. 2 (left) Growth rate change as function of m_w and m_o for InGaAs sandwiched between Q1.25 layers
Fig. 3 (right) PL peak wavelengths of InGaAs QW stack for different m_w and m_o



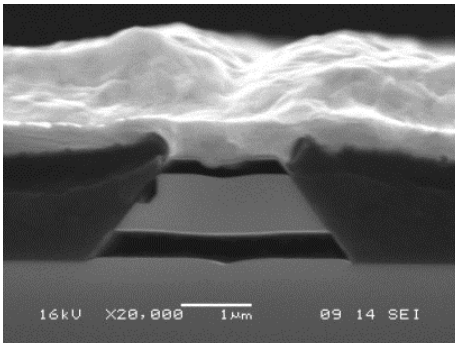


Fig. 4 (left) Simulated TE optical mode profile in SAG mesa
Fig. 5 (right) Cross section of fully processed SAG laser (m_0 3.6µm, m_w 20µm)

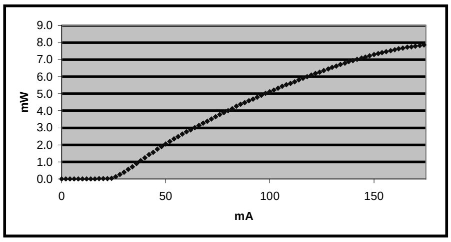


Fig. 6 LI plot for as cleaved laser (cavity length 400 µm, pulsed injection, normalised power)

References

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